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Euthanasia and slaughter of livestock

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Euthanasia is defined as a humane death that occurs without pain and distress.[1] Physical methods of euthanasia are used in slaughter plants and in clinical practice. These methods are unpleasant to watch, but humane when used properly. In some cases, the most humane euthanasia method for an injured cow or horse is by gunshot, because fear and anxiety are minimized.

During the past 20 years, the author has worked in more than 100 slaughter plants as a consultant for improving handling techniques and equipment used for slaughter in an effort to improve the humaneness of slaughter. When slaughter is performed properly, it is euthanasia; however, when it is performed improperly, animal suffering may result. There is a tremendous need for veterinarians to increase their knowledge of physical methods of euthanasia and humane slaughter. Observations by the author at slaughter plants indicate that some veterinarians lack such practical and scientific knowledge. It is the responsibility of veterinarians to enforce the Humane Methods of Slaughter Act of 1978.[2] The purpose of this report is to provide veterinarians with practical and scientific information on the use of captive bolt guns, electrical stunning, CO_2 anesthesia, and ritual slaughter.

Captive Bolt and Gunshot

Gunshot and penetrating captive bolt are acceptable methods of euthanasia, according to AVMA guidelines.[1] The captive-bolt gun or firearm must be aimed at the correct location on the animal's forehead (Fig 1). It should not be aimed between the eyes. The hollow behind the poll also should be avoided, because it is less effective than the forehead position.[3] In sheep, the shot must be aimed at the top of the head because the front of the skull is thick. A captive-bolt gun must be placed firmly against the skull and a firearm must be held 5 to 20 cm away from the skull. Penetrating captive-bolt guns that are actuated by a blank cartridge can be obtained.[a] Practical experience has shown that a 22-caliber firearm is sufficient for cattle and horses. A larger caliber should be used on large bulls, boars, or buffalo.

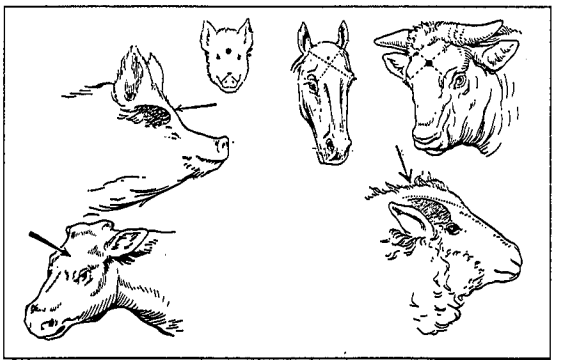

Figure 1—Correct position for euthanasia of livestock by use of a captive-bolt gun or firearm.

A captive-bolt gun kills the animal by concussive force and penetration of the bolt.[4,5] A nonpenetrating, mushroom-head captive bolt only stuns the animal, thus, it cannot be used as the sole method of euthanasia.[1] A nonpenetrating captive bolt must be followed by an adjunctive method, such as exsanguination.[1] The gun must be carefully cleaned and maintained to achieve maximal hitting power. Observations by the author in slaughter plants indicate that poor gun maintenance is a major cause of poor stunning, in which more than one shot is required. In large, high-speed plants, maintenance personnel must be dedicated to servicing captive-bolt guns.[6] Many large slaughter plants use pneumatic powered captive-bolt guns. To obtain maximal hitting power, the gun must be supplied with sufficient air pressure and air volume per the manufacturer's recommendations.

When a standing animal is shot, it should in-

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[a]Koch Supplies, Kansas City, Mo.

stantly drop to the floor. In cattle, the neck contracts in a spasm for 5 to 10 seconds. Hogs have violent convulsions. Observations by the author indicate that this can occur even when the brain and part of the spinal cord have been destroyed. These are normal reactions. Rhythmic breathing must be absent and the animal must not moan, bellow, or squeal.[7] All eye reflexes should be absent.[7] Gasping or gagging reflexes are permissible because they are signs of a dying brain.[7] Within 10 seconds, the neck and head should be completely relaxed. In a clinical situation and in a slaughter plant, the animal's limbs may make uncoordinated movements for several minutes.

Electric Stunning and Electrocution

Electric stunning is not recommended for use in research facilities or on farms. Stunning and euthanasia by electrocution is acceptable only conditionally, because special skills and equipment are required.[1] Restraint equipment is required to hold the animal so that the electrodes can be placed in the correct position. Use of an electrical cord plugged into 115 V house current to kill piglets or other livestock is not acceptable. Piglets less than three weeks old should be euthanatized by appropriate administration of pharmaceutical agents or by application of blunt trauma to the forehead.[8] Captive bolt or gunshot can be used on older pigs.

Properly applied electrical stunning in a slaughter plant induces instantaneous unconsciousness, and is approved under the Humane Methods of Slaughter Act of 1978.[2] Sufficient amperage must be applied through the brain to induce a grand-mal epileptic seizure.[9,10] The animal's brain must be in the current path between the two electrodes.

Hogs in small locker plants or meat science laboratories often are stunned with head-only reversible electric stunning. To prevent return to sensibility, the animal must be exsanguinated within 30 seconds,[10] and some researchers recommend 10 to 15 seconds.[11] The author has observed that delays between reversible head-only stunning and exsanguination are common in small locker plants because the hoist is too slow. Inadequate equipment causes severe welfare problems.

In large pork and sheep slaughter plants, animals are held in a conveyor restrainer, and stunning that induces cardiac arrest (cardiac-arrest stunning) is used. The interval between stunning to exsanguination is less critical. One electrode is placed on the forehead or in the hollow behind the ears, and the second electrode is placed on the back, side of the body, or forelimb. In pigs and sheep, this method simultaneously induces instantaneous insensibility and cardiac arrest.[10,12] The head electrode must not be placed on the neck, because failure to induce an epileptic seizure causes suffering.[12] Properly and poorly stunned animals look similar, because cardiac arrest masks the clinical signs of the grand-mal seizure.[12] The animal may be conscious, but appears to be properly stunned.

When cardiac-arrest stunning is used, electrode positions and electrical settings must be verified by measures of electrical or neurotransmitter activity in the brain.[9,13] Only scientifically verified electrode positions and electrical settings should be used. Visual assessment must not be used to verify new settings for cardiac-arrest stunning. New settings must be verified by scientific research to ensure that instantaneous insensibility occurs.

For large (108 kg) market-weight hogs, a minimum of 1.25 A at 300 V for one second should be used.[10] For slightly smaller pigs, the voltage can be dropped to 250 V.[7] For sheep, a minimum of 1 A at 375 V for three seconds should be used.[14] In New Zealand, electrical stunning is being successfully used in cattle.[15-17] Electrical stunning of cattle requires the use of a restraint device to hold the head.[17] Unlike pigs or sheep, cattle must have a stunning current (2.5 A) passed through the brain before the head-to-body cardiac-arrest current is applied.[17] In one study,[15] a single, 400 V 1.5 A current passed from the neck to the brisket failed to induce epileptic form changes in the electroencephalographic recordings. Equipment manufacturers have found that a minimum of 400 to 450 V is required to achieve insensibility. Practical experience indicates that greater amperages and voltages are required to achieve insensibility than to achieve cardiac arrest.

Amperage (current) is the most important factor in inducing unconsciousness.[9] Modern stunning circuits use a constant amperage power source, and voltage (electrical potential) varies with animal resistance. Some slaughter plants attempt to reduce meat quality defects by lowering the amperage or using high frequencies. This must not be permitted. Petechial hemorrhages can be minimized by the use of a constant amperage power supply.[18] Electrical frequencies of over 200 Hz must not be used unless they are scientifically verified.[9] In one report, a frequency of 500 Hz failed to induce unconsciousness. Most electrical stunning devices operate at 50 to 60 Hz.

Assessment of Stunning Efficacy in Slaughter Plants

Head-only reversible electric stunning of pigs and sheep causes an initial spasm (tonic phase), which lasts approximately 10 seconds. After the tonic phase, kicking begins (clonic phase).[9] Animals stunned with head-only reversible stunning kick more vigorously than animals in cardiac arrest. Animals are unconscious during the tonic and clonic phases. After a stunned animal is hung upside-down prior to exsanguination, the field methods for verifying insensibility are similar for captive bolt and electric stunning. Eye reflexes and blinking must be absent. In electrically stunned animals, eye

reflexes should be checked 20 to 30 seconds after stunning. Prior to this time, eye reflexes are masked by the epileptic seizure. Veterinarians also need to check amperages, voltages, and electrode positioning to ensure that the stunner is being operated correctly.

In animals that have been shot with a captive bolt or stunned electrically, the limbs may move. Random limb movement should be ignored, but a limb that responds vigorously in response to a stimulus is a possible sign of return to sensibility. After the animal is hung on the overhead rail, the head must hang straight down and the neck should be limp. The tongue should hang out and the ears should droop down. Gasping and gagging reflexes are permissible,[7] but rhythmic breathing and vocalization must be absent. The animals must not have an arched-back righting reflex. Fully conscious animals suspended upside-down arch their backs in an attempt to lift their heads.

Carbon Dioxide Stunning

Carbon dioxide stunning is an approved method for inducing insensibility under the Humane Methods of Slaughter Act of 1978.[2] The AVMA states that CO_2 is an acceptable method of euthanasia, but other methods are preferable because large animals, such as swine, appear to be more distressed than small laboratory animals. In both pigs and human beings, there is great variability in reactions to CO_2.[19-23] Swedish Yorkshire pigs react well to CO_2, and the motoric excitation phase begins after the electroencephalograph, indicating second-stage anesthesia.[24] Hoenderken[10] found that the excitation phase started before the pig was unconscious.[10] Visual assessment by other investigators has shown that halothane-positive pigs have a greater amount of excitation than halothane-negative pigs.[21] Administration of halothane is used as a test to detect pigs that have porcine stress syndrome. Such pigs react to halothane by becoming rigid. There is concern that some of the pigs sensitive to halothane may be conscious during an initial excitation phase.[21] Observations by the author revealed that some pigs quietly lost consciousness when exposed to CO_2, whereas other pigs violently struggled when they first sniffed the gas. The encephalographic measurements that have been performed on the Swedish Yorkshire breed should be performed on pigs of various breeds that are sensitive and nonsensitive to halothane. At this time, available research data suggest that CO_2 is a good euthanasia method for certain genetic types of pigs, but may possibly cause discomfort in others.

To reduce excitation during anesthetic induction, pigs should be rapidly exposed to 80 to 90% CO_2.[21] Veterinarians at slaughter plants should monitor CO_2 concentrations because plant management may be tempted to lower concentrations to save money. Observations in the field have indicated that pigs that walk quietly into the CO_2 chamber have a milder excitation phase than agitated, excited pigs. A new CO_2 stunning system in Denmark appeared to greatly reduce excitement and squealing during handling because groups of five pigs were moved into the chamber at one time. The author observed that these pigs had little reaction when they first contacted the gas, and the motorific excitation phase appeared to occur after they became unconscious. One possible explanation for this observation is that Denmark has a low prevalence of pigs sensitive to halothane.

Preslaughter Stress

Properly performed slaughter induces cortisol concentrations equal to or less than that induced by on-farm handling and restraint when a captive bolt is used.[25-29] When preslaughter handling is performed properly, cattle should move through the chute at a slow walk and calmly enter the stunning area without balking. To reduce stress, cattle should be stunned immediately after they enter the stunning box or restrainer. Cattle should not have signs of visible agitation, such as bellowing or rearing. In a well-designed handling system, the author has been able to move 8 of 10 cattle into the stunning pen or restrainer without use of an electric prod.

Findings in studies[28-30] have indicated that cortisol concentrations can double or triple when cattle slip on slick floors, are restrained in poorly designed equipment, or are over-prodded. When this occurs, cortisol concentrations may greatly exceed on-farm handling concentrations. Epinephrine and norepinephrine are of limited value for evaluating preslaughter stress, because electric and captive-bolt stunning trigger massive release of these substances.[31,32] When stunning is performed correctly, the animal does not feel any discomfort because it is unconscious when the hormones are released.

In large (1,000 head/h) pork-slaughter plants, it is likely that hogs experience more stress than from on-farm handling because they squeal and jam together as they move through the single-file chute. To improve conditions for the hogs' welfare and for pork quality, two restrainer systems may be required in high-speed plants. Providing confinement hogs with rubber hoses to chew on and additional contact with people during finishing results in calmer hogs that are easier to handle. Indiscriminate genetic selection for leanness and rapid growth tends to produce nervous, excitable hogs.[33]

Behavioral Principles

People who handle animals must be trained to use behavioral principles. They need to understand the animal's flight zone (Fig 2) and point of balance.[34,35] To make an animal move forward, the handler must stand behind the point of balance. Handlers also should work on the edge of the an-

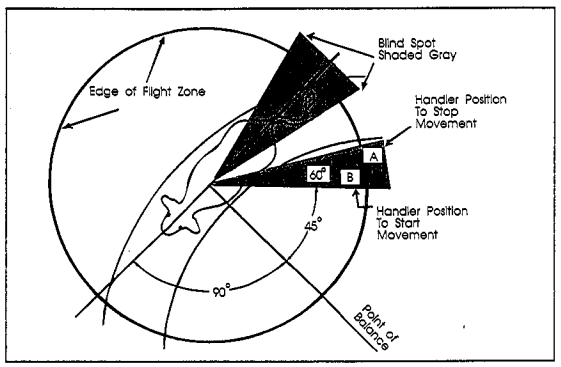

Figure 2—Diagram of an animal's flight zone (personal space). To move the animal forward, the handler must stand behind the point of balance at the shoulder and should work on the edge of the flight zone. Moving to position B causes the animal to move forward, whereas moving to position A usually causes the animal to stop.

imal's flight zone because deep penetration of the flight zone may cause panic or vigorous escape reactions. Tame animals have a smaller flight zone than wild animals.

In new and old facilities, distractions that cause animals to balk must be eliminated. The author has observed that distractions, such as shadows, puddles, light reflections on the floor, and visible people ahead, can ruin the performance of a well-designed system. Moving an overhead lamp to eliminate a water reflection or installing a shield to prevent approaching animals from seeing a person ahead facilitates animal movement. Veterinarians need to look up chutes and see what the animals see. Lamps can be used to attract animals into dark chutes and restrainers. The light must not glare in the eyes of approaching animals or cause reflections off the floor or chute walls. Equipment should be designed to minimize noise. High pitched motor sounds, air hissing, and metal clanging and banging are more likely to cause excitement than the low rumble of a conveyor. Ventilation systems must not blow slaughter or rendering smells into the faces of approaching animals. The novelty of a smell or shadow causes animals to balk. Novelty is highly stressful when livestock are being handled in an unfamiliar environment. The author has observed that in a familiar environment, such as a feedlot pen, animals initially fear a novel stimulus, such as a loader used for pen cleaning. After they learn that it will not hurt them, it becomes environmental enrichment and the animals may approach and lick a parked machine. A spot of blood on the floor of the chute sometimes impedes animal movement. This appears to be attributable to visual contrast. The author has observed that throwing a piece of paper in a chute has the same effect.

Effect of Blood

Observations by the author during new restraint equipment start-ups in many plants indicate that blood from relatively calm cattle does not appear to frighten the next animal that enters a restrainer. The animal usually voluntarily enters a restrainer that is covered with blood. Some cattle may lick the blood. Blood or saliva from a highly stressed animal, however, appears to upset other cattle. If an animal becomes frenzied for several minutes, the cattle next in line often balk and refuse to enter the restrainer. After the equipment is washed, however, the cattle will enter. In one plant, a steer refused to walk over the spot where he had flipped over backward, and then refused to walk over dribbles of saliva that were smeared on the floor where he had flipped over. He voluntarily reentered the chute three times, but when he reached his saliva on the floor, he backed up through the chute for over 15 m. There is some evidence that there may be a "smell-of-fear" substance. In one study,[36,37] blood from stressed rats was avoided by other rats, but human or guinea pig blood had no effect. According to animal behaviorist, Eible-Eihesfeldt, if a rat is killed instantly by a trap, the trap can be used again, but if the trap fails to kill instantly, it will be avoided by the other rats.[38]

Possibly, the substance that the cattle are smelling is cortisol or some other substance that is secreted in conjunction with cortisol. Cortisol is present in the blood and saliva of cattle.[39] Cortisol is a time-dependent measure, up to 20 minutes is required to reach peak values.[40] The time course of cortisol secretion fits the author's observations. If an animal is stressed for only a few seconds by an electric prod, the next animal usually remains calm and walks into the restrainer. The most serious balking and refusals to enter occur after an animal has become seriously stressed by becoming jammed in a piece of equipment. The other cattle often balk and refuse to enter for several hours.

Design and Operation of Restraint Devices

Observations by the author in more than 100 slaughter plants indicate that the attitude of management is the single most important factor that determines how animals are treated.[41] Plants with good animal welfare practices have a manager who acts as their conscience. He or she is involved enough to care but not so involved that he or she becomes numb and desensitized to animal suffering. The author's observations also indicate that abuses, such as excessive prodding, dragging downed crippled animals, or running animals over the top of a downed animal, often occur when management is lax. The author has observed that in a few poorly managed plants, up to 10% of the cattle must be shot more than once with a captive bolt to render them insensible. It is the responsibility of the manager to enforce high standards of animal welfare. Good managers take the time to incrementally improve livestock handling. Perfecting handling techniques can take several months of

sustained effort. There have been great improvements in equipment to handle and euthanatize livestock in slaughter plants. Unfortunately in the United States, advances in equipment have not been paralleled by similar advances in management. In many plants, management attitude toward animal treatment has improved, but in some plants animal handling has become rougher. This is attributable to an overemphasis on speed or management personnel who do not care.

Large slaughter plants use a variety of restraint devices for holding animals during stunning and slaughter.[35,42,43] Proper operation is essential for good animal welfare. The best equipment causes stress and suffering if it is operated roughly and animals are poked repeatedly with electric prods.

It is beyond the scope of this article to discuss equipment design in detail, but some basic principles should be mentioned. Solid sides should be installed on chutes, crowd pens, and restraint devices.[34] Solid sides keep animals calmer because they block outside distractions and prevent animals from seeing people deep inside their flight zone. Solid sides also make an animal feel more secure because there is a solid barrier between it and a threatening person. A basic principle is that an animal remains calmer in a restraint device if its vision is blocked until it has the feeling of restraint.[43,44] On conveyor restrainers, the solid hold-down over the entrance must be long enough to block the animal's vision until its rear feet are off the entrance ramp and it is completely settled down on the conveyor.[42]

A second basic principle is that sudden jerky motions of equipment or people excite animals, and slow steady movements have a calming effect. A third principle is the concept of optimal pressure. A restraint device should apply enough pressure to provide a feeling of restraint, but excessive pressure, which would cause pain, must be avoided. If an animal struggles because of excessive pressure, the pressure should be slowly released. When head restraint equipment is used, the animal should be stunned or ritually slaughtered immediately after the head is restrained. On restraint devices with moving parts that press against the animal, pressure limiting valves must be installed to prevent discomfort. A pressure limiting valve automatically prevents a careless operator from applying excessive pressure.

Ritual Slaughter

Ritual slaughter is slaughter performed according to the dietary codes of Jews or Muslims. Cattle, sheep, or goats are exsanguinated by a throat cut without first being rendered unconscious by preslaughter stunning. Ritual slaughter is exempt from the Humane Methods of Slaughter Act of 1978 to protect religious freedom.[2]

Because ritual slaughter is exempt, some plants use cruel methods of restraint, such as suspending a conscious animal by a chain wrapped around one hind limb. In other plants, the animal is held in a restrainer that holds it in an upright position.[43,45,46] Whether or not ritual slaughter conforms to the requirements of euthanasia is a controversial question. When ritual slaughter is being evaluated, the variable of restraint method must be separated from the act of throat cutting without prior stunning. Distressful restraint methods mask the animals' reactions to the cut.

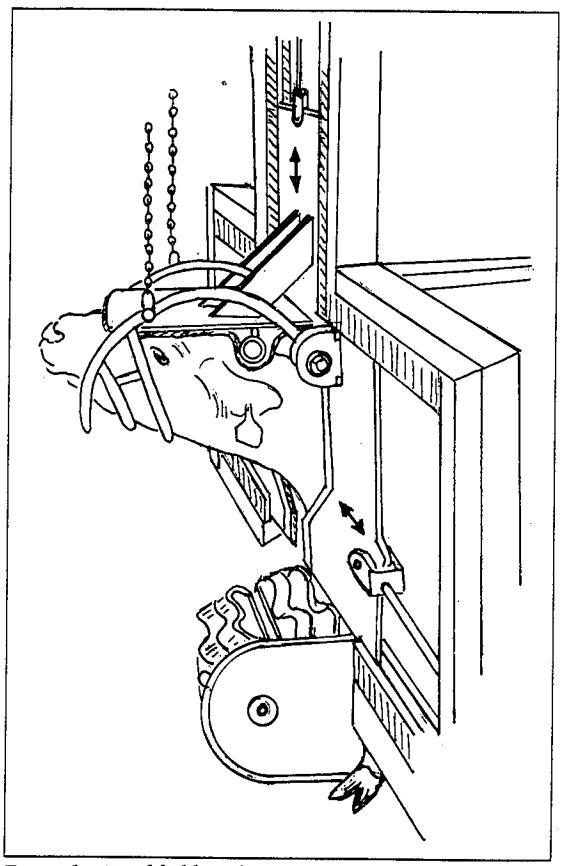

Figure 3—Head-holding device for ritual slaughter mounted on a double-rail (center-track) restrainer. The chin lift and forehead bracket should be equipped with pressure-limiting valves. The 15-cm wide forehead bracket with a 7.5-cm round pipe behind the animal's poll holds the animal's head securely with little pressure. The pipe prevents the animal from pulling its head out. The pipe and forehead bracket are covered with rubber belting.

The author designed and operated four state-of-the-art restraint devices that hold cattle and calves in a comfortable upright position during kosher (Jewish; Fig 3) slaughter.[35,42,43,46] To determine whether cattle feel the throat cut, at one plant the author deliberately applied the head restrainer so lightly that the animals could pull their heads out. None of the 10 cattle moved or attempted to pull their heads out. Observations of hundreds of cattle and calves during kosher slaughter indicated that there was a slight quiver when the knife first contacted the throat. Invasion of the cattle's flight zone by touching its head caused a bigger reaction. In another informal experiment, mature bulls and

Holstein cows were gently restrained in a head holder with no body restraint. All of them stood still during the cut and did not appear to feel it. Disturbing the edges of the incision or bumping it against the equipment, however, is likely to cause pain. Observations by the author also indicated that the head must be restrained in such a manner that the incision does not close back over the knife. Cattle and sheep struggle violently if the edges of the incision touch during the cut.

The design of the knife and the cutting technique appeared to be critical in preventing the animal from reacting to the cut. In kosher slaughter, a straight, razor-sharp knife that is twice the width of the throat is required, and the cut must be made in a single continuous motion. For halal (Muslim) slaughter, there are no knife-design requirements. Halal slaughter performed with short knives and multiple hacking cuts resulted in a vigorous reaction from cattle. Fortunately, many Muslim religious authorities accept preslaughter stunning. Muslims should be encouraged to stun the cattle or use long, straight, razor-sharp knives that are similar to the ones used for kosher slaughter.

Investigators agree that kosher slaughter does not induce instantaneous unconsciousness.[47,48,b] In some cattle, consciousness is prolonged for over 60 seconds. Observations by the author indicated that near immediate collapse can be induced in over 95% of cattle if the ritual slaughterer makes a rapid, deep cut close to the jawbone.[45] Further observations indicated that calm cows and bulls lose sensibility and collapse more quickly than cattle with visible signs of agitation. The author has observed that cattle that fight restraint are more likely to have prolonged sensibility. Gentle operation of restraint devices facilitates rapid loss of sensibility.

Cattle do not appear distressed even when the onset of unconsciousness is delayed. Pain and distress cannot be determined by measurements such as an electroencephalogram. Behavioral observations, however, are valid measures for assessing pain.[49] The author has observed that cattle appear unaware that their throat is cut. Investigators in New Zealand have made similar observations.[50] Immediately after the cut, the head holder should be loosened slightly to allow the animal to relax. The author also has observed that after the head restraint is released, the animal collapses almost immediately or stands and looks around like a normal, alert animal. Within 5 to 60 seconds, cattle go into a hypoxic spasm and sensibility appears to be lost. The spasms are similar to those that occur when cattle become unconscious in a headgate that is used for restraint in feedlots. Practical experience has shown that pressure on the carotid arteries and surrounding areas of the neck from a V-shaped headgate stanchion can kill cattle within 30 seconds.

[b]Nangeroni LL, Kennett PD. Department of Physiology, Cornell University, Ithaca, NY: Unpublished data, 1963.

Even though exsanguination is not an approved method of euthanasia by the AVMA,[1] the author has observed that kosher slaughter performed with the long, straight, razor-sharp knife does not appear to be painful. This is an area that needs further research. One can conclude that it is probably less distressful than poorly performed captive-bolt or electrical stunning methods, which release large amounts of epinephrine.[31,32]

Welfare can be greatly improved by use of a device that restrains the animal in a comfortable upright position. For cattle and calves, a conveyor restrainer or an upright restraint pen can be used.[42,43,46] In small plants, sheep or goats can be held by a person. If an upright pen is used, vertical travel of the lift under the animal's belly should be restricted to 71 cm to prevent the animal from being lifted off the floor. A pressure limiting valve must be installed on the head holder and rear pusher gate.[43,45] Many existing upright restraint boxes apply excessive pressure. To prevent excessive bending of the neck, the head holder should position the animal's forehead parallel to the floor. Equipping the head holder with a 15-cm wide, rubber covered forehead bracket will make the head holder more comfortable (Fig 3). The animal should stand in the box with its back level. An arched back is a sign of excessive pusher-gate pressure. In some plants, animals are removed from the restrainer before they become unconscious. Discomfort to the animal can be minimized by allowing it to lapse into unconsciousness before it is removed from the restrainer.

During the past five years, many large kosher slaughter plants for cattle have replaced shackling and hoisting with upright restraint. Large numbers of veal calves and sheep, however, are still shackled and hoisted. Progressive plant owners have installed upright restraint equipment, but unfortunately there are some plant owners who still refuse to install humane restraint equipment because they are not legally required to do so. Animal handling guidelines published by the American Meat Institute recommend the use of upright restraint.[6]

Conclusions

The technology exists that allows slaughter and euthanasia to be one. Although some slaughter plants maintain high animal welfare standards, there are others in which management allows abuses to occur. After adequate equipment has been installed, the single most important determinant of good animal welfare is the attitude of management. Good equipment provides the tools that make humane slaughter and handling possible, but it is useless unless it has good management to go with it.

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